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Inspection of Railroad Masonry

.. BY ..

HENRY RHIEL GARDEN

THESIS

FOR

DEGREE OF BACHELOR OF SCIENCE

IN CIVIL ENGINEERING

COLLEGE OF ENGINEERING

UNIVERSITY OF ILLINOIS

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ENTITLED INSPECTION OF RAILROAD MASONRY

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OF Bachelor of Science in Civil Engineering.

Isa O Baker

HEAD OF DEPARTMENT OF Civil Engineering.

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HEAD OF DEPARTMENT OF CIVIL ENGINEERING

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Inspection of Railroad Masonry.

It sometimes happens that an engineer without practical experience in inspecting railroad masonry is called upon to act in that capacity; and since apparently nothing has been written on this subject; it is proposed to discuss the facts to be borne in mind and the points to be watched during the progress of the work. It will be assumed that the reader is familiar with the ordinary technical terms and also with the text books used in college courses. This article is intended to supplement works of that nature.

This discussion will be divided into three parts. The first will treat of the general instructions concerning the work. Next the actual work of inspection will be considered, and then will follow a brief discussion of the relations of the inspector to the workmen and to the contractor.

1. General Instructions.

In the performance of his duties the inspector will always be governed by the instructions received from his superior

officer and by the specifications; but his interpretation of these may be modified by the contract price of the work, by a knowledge of the detriment to the railroad of a delay in completing the work, and by the contractor's standing with the company.

Superior's Instructions. The first in order of importance is of course the instructions of his superior, more especially so if they are written. These should be followed more or less literally according to the inspector's acquaintance with the methods of the person under whom he works. If the inspector is a new man he cannot do better than follow the instructions literally.

Specifications. Specifications for masonry should be written clearly, because they are the contractors' guide in preparing their bids, and it is unfair either to the company or to the contractor if the specifications are construed differently by the inspector and the bidders. As an aid to a clear understanding of the specifications,

all of the clauses relating to the same subject should be grouped together. Care should also be used in writing specifications that conflicts do not occur between clauses related to each other. For example, a particular set of specifications requires: "headers and stretchers to alternate"; "there shall be at least one header in every six feet"; and "the length of a stretcher shall measure at least $2\frac{1}{2}$ times its height." These clauses disqualify a course over 2 feet 5 inches thick, an effect which no doubt was not the intention.

Specifications are written with the intention of securing good work, and if this is secured, no objection should be made, even though the work is not exactly according to specifications.

Contract Price. The contract price will sometimes be a help in determining what grade of work the contracting parties had in mind. For instance, if the price is about \$7.00 per cubic yard, the stone to be of a good grade of limestone and the contractor to furnish

all labor and materials, the inspector will have good cause to doubt whether maximum joints of 6 inches in the interior of the wall were expected, even if they are called for in the specifications. Observation and experience would teach the inspector that that grade of work could not be done for the price stated.

Delay. Occasionally it happens that a delay to a piece of work will be quite costly to the railroad company, in which case work will be accepted which under ordinary circumstances would not be permitted. The inspector would receive special instructions from his superior in a case of this kind, and in acting on them he should not let the contractor learn of the situation, as the work might suffer as a consequence.

Contractor's Reputation. The standing of the contractor with the railroad company will possibly be a useful bit of information to a new inspector. If the contractor has been doing work on the road for some years, it will be fair to suppose that his

work has been found satisfactory and the new inspector will do well to make inquiries before deciding on any constantly recurring question concerning the work, where there is a difference of opinion between the inspector and the contractor.

2. Details of Inspection.

The above remarks apply to the general features of the work, but the chief need of an inspector is to look after the details, to see that no mistakes are made and the work is not slighted. The actual work of inspection will be discussed under the following heads: Material, Foundations, Cutting of Stone, Setting the Stone, Bond, joints, Grouting, Filling, Appearance of Walls, Pointing, and Materials and Accounts. These subjects will be considered in the above order, which is about that in which they would be expected to present themselves in practice.

Material. The material should be examined from time to time to see that it is of the required standard, and any that is condemned should be removed at once.

Unless rejected material is disposed of under the inspection orders, it frequently finds its way into the wall where it is liable to escape detection.

The stone should be inspected, especially when it is delivered on the site, for flaws such as dries and sower cracks. A dry is a seam of foreign matter which lacks the cementing properties possessed by the rest of the mass. The objection to a seam of this kind is that the stone will break at the dry as a result of the action of frost and water. Stone cutters often attempt to "blind" a dry by pointing the stone away from the seam. Any stone that has faint marks radiating from a common line may be almost undoubtedly from the tool marks alone; for inspection scarcely always shows a dry as the line from which the tool marks radiate. It is common as this practice is, inspectors of some experience are deceived by it. In looking for dries care should be used to distinguish between them and the peculiar local formations that often appear in stone but which

do not affect its usefulness. The most common of these is the glass seam which is of an entirely different formation from the stone itself and is so far from a flaw, that the stone will break along side of or across the seam when hit by a hammer but never at the seam. Powder cracks are the result of blasting in quarrying and are quite easy to detect. Stones that have flaws in them are often used where they will be protected from the action of frost and water, as in the interior of the wall or on the back face of abutments, above the water and below the frost line; and when so placed they are not a serious detriment to the work though sound stone are of course to be preferred.

The sand will be taken from some bank previously decided upon which it be either within easy teaming distance of the work or on the company's line at no great distance. The standard sand for that particular piece of work will therefore have been decided upon and the inspector will make tests occasionally to see that a proper

grade is not being delivered. A comparison for coarseness, sharpness and cleanness is made by rubbing it between the fingers.

The cement will probably be of a specified brand and its action in the wall should be noticed from time to time to see that there is no unusual deviation from the average. Cement will probably be delivered on the work in bags, and when furnished by the railroad company the inspector should see that it is properly stored by the contractor so that no damage from moisture will occur. When the cement is furnished by the contractor and an occasional bag is found which is partly set, the inspector can easily allow the partially damaged sacks to pass as though they were not damaged. The difference to the strength of the work is not worth troubling about.

However, if these partly damaged bags are rather numerous, then the proper proportion of sand and cement should be insisted upon.

Foundations. It rarely happens that a reasonable inspector has any foundation work

except where concrete is used. When concreting is to be done by a masonry crew, the inspector usually finds that he has men unused to concrete work, who are anxious to get the foundation in and ^{to} commence the easier and more pleasant work to which they are accustomed. Under these conditions it will require watchfulness and diplomacy on the part of the inspector to secure fairly good work. Particular care should be taken to keep the broken stone reasonably clean, and to mix the concrete moderately wet. There is a difference of opinion as to whether wet or dry concrete gives the better results, but it is safe to say that it requires great care to obtain the best results with dry concrete, while it does not take much attention, with even indifferent workmanship, to secure a good foundation when wet concrete is used. The concrete should be rammed into place until the water flushes to the top.

Cutting. On ordinary bridge work the face of the stone is left rough, excepting a line is pitched to which the stone is set. The beds and joints are usually cut

a little hollow rather than to a true plane. By doing so the stone cutters can do their work with rougher and faster tools and the irregularities will all be within the dimensions of the stone. This method of cutting is cheaper than if all surfaces were dressed to true planes at right angles to one another, and probably has very little to do with the life or strength of a piece of work.

When the stone are cut at the quarry they are platted for certain spaces in a given course; and when, through some error, a given stone is too small to fill its assigned space with the proper sized joints, some difficulty may be experienced - as will be discussed under the head joints.

Setting the stone. The most of the inspector's time will be spent on the wall watching the work of setting the face stone and backing, and also in inspecting the filling of the joints between the large stone.

All surfaces of building stone are covered with more or less powdered stone which will prevent a firm adhesion of the mortar, and therefore any surface which is to come

in contact with mortar should be wetted. With large stone this is done by sprinkling the stone on which the mortar bed is to be spread, and then after the bed is spread sprinkling the mortar. Small stones to be used in filling should be drenched before being placed in the wall. Masons object to handling wet stone because it soon wears out the skin of their hands. This objection can be removed by having the mortar 'mixed thin', which will give the same results as stiff mortar and wet stone, and further the thin mortar is more likely to fill the interstices than stiff mortar.

During the course of construction the top of the wall should be frequently swept to remove any foreign material that may have collected and also to remove any unused mortar that has set. Strictly speaking it is not necessary to sweep the wall except just before spreading a mortar bed; but the inspector is liable to be called away at any time, and it is therefore well to keep the wall always reasonably clean, and besides the work will then look better for an unexpected visit of the inspector's superior officer.

In setting a heavy stone the mortar bed is spread as heavy as the head mason judges is necessary, and the stone is slowly lowered to place. If the stone is too low after being placed, it is raised and more mortar is spread. If the stone is high, it is settled either by pounding it with a heavy wooden ram or by shaking it down with bars. To shake a stone into place a slight lift is taken with bars and at the same time the bars are moved back and forth sidewise. This gives the stone a lateral motion which gradually forces the mortar from beneath it and allows it to settle to its proper place. If only one side of the stone is too high, a bar is placed under the lower side to hold it up and the higher side settled as just described.

In shaking a stone to position it should be lifted only enough to permit it to be moved sidewise since if it is lifted too high the mortar bed becomes concave on top and the stone will rock. If this condition exists, it can only be remedied by re-bidding. It is much easier and faster to shake a stone to position than to settle it with a ram.

Masons sometimes attempt to hold a stone up to place by slipping a thin spawl beneath it. This is bad practice and should not be permitted, for the spawl is almost sure to crush under additional weight and allow a settlement in the wall.

Occasionally a stone, after being set can be given a slight rotary motion without much effort; the stone moving ^{as} a pivot. This is due to the fact that the mortar has been compressed by the weight of the stone, and the water has been forced to the top of the mortar bed where it forms a thin layer of very soft mortar immediately below the stone which gives but very little resistance to a slight lateral movement of the stone. This is commonly known as "swimming" and disappears when the mortar sets.

Bond: The bond of the masonry is of the utmost importance since it determines the strength of the wall. The joints may be bad, the mortar poor and the workmanship of an inferior quality; but if the bond is good the wall will still have considerable strength. On the other hand, if the bond is poor the wall will surely

or weak. The amount of break on the face is always given in the specifications, and as it is an easy matter to fulfill this requirement it should always be enforced. In turning an arch great care should be taken to secure the proper bond; for the face is covered by the lagging and a short break will not be found until the centers are removed when no change can be made. The bond in the body and on the back face of the wall should receive constant attention. It is common practice to allow less break in these parts of the wall than on the face but at least 8 or 9 inches should be insisted on. The difference between bed measurements of headers and stretchers largely determine the interior bond, and for this reason as great a variation as possible is desirable. The tendency is to make a header short in the length perpendicular to its face in order to decrease the percent of cut stone in the work and hence the cost per yard of the whole.

Joints. The thickness of the joints varies, for different grades of masonry from $\frac{3}{8}$ of an inch for arch-stone masonry up to 2 or 3 inches for second-class work. The accuracy

of the cutting of the stone determines to what width of joint it may be set. As there is ordinarily no good reason why the stone should not be cut well enough so that the specifications may be fulfilled, large joints due to rough cutting should not be allowed.

Joints on the face are usually limited to $\frac{1}{8}$ inch, but it frequently happens that to enforce this rule means a loss of considerable time to the contractor, especially if a special order has to be sent to the quarry for a new stone. A discrepancy can sometimes be made up by varying all the stones between the two determining points by slightly increasing the thickness of each joint. If the use of a particular joint will require a $\frac{1}{4}$ inch joint, or if the stone is condemned stone, will be a delay of several days while another stone is being sent from the quarry, what should the inspector do? If the work has been uniformly good and the short stone is clearly an accident, the inspector will no doubt accept the stone. But if a week later a like condition demands $\frac{1}{8}$ inch joints, what is he to do this time? Case

similar to this frequently occur, though not always in regard to joints; and the inspector is often at a loss to know just what course to pursue. If there is a disposition to slight the work generally and these cases are somewhat frequent, it will be wise to have the work done properly regardless of the delay, for then it will probably not be long before a decided improvement will occur.

Vertical joints in the back face should not be more than 2 inches wide unless they are filled with small stones set with mortar. The width of the vertical joints in the interior of the wall is usually determined by the stock of backing on hand, for the contractor or his foreman will choose a backing stone that will require the least "rubbleing up", since large interior joints make the work slower and more expensive.

For this reason criticism is rarely made of the size of joints between backing stones unless the work is to be of a superior quality.

Grout. Grout is not as satisfactory as stiff mortar, because it is hard to hold within the desired space and often after a joint has been left as being filled it will be found

that the grout has run out from one part and left the remainder of the joint looking as though it were thoroughly filled.

In turning an arch the beds are spread and the end joints filled with mortar the same as in the building of the side walls; but after the point is reached where the mortar can not be spread, the shutting stones are set on the lagging in their proper relative positions until all of the arch stones are set and then the joints are filled with grout. In doing this grouting care must be used to keep all passages between the stones clear for the running of the grout so that no portion will remain unfilled. Also the face of the arch ring should be watched to see that the grout does not escape through the lagging and leave empty joints behind.

Rubbling Up. Rubbling up is filling the interior joints with mortar and rubble, and is frequently called "filling." This part of the work takes the most time and is most often slighted because it is done by cheaper labor. In "filling" one of two conditions will prevail depending on whether the railroad

company or the contractor furnishes the cement.

If the first, the tendency will be for the masons to use more mortar than they should, because it will take much less time to shovel a joint full of mortar than to fill it with spawls properly set in mortar. This can be stopped by the inspector's watching the work and insisting on the proper proportion of mortar and stone. If the inspector is away while a joint is being filled, he can judge somewhat of the kind of work by sounding the joint with a bar of iron. If the joint is chiefly filled with mortar, the bar can be easily forced to the bottom of the joint.

When the cement is furnished by the contractor, the result to be expected is that stone will be put in dry. This is sometimes done either by throwing in dry stone until the joint is nearly full and then commencing to use mortar; or occasionally using no mortar until the joint is full of stone and then spreading mortar over the top, and making the joint look as though it had

been properly filled. If the inspector is on the wall while the work is being done, he can easily stop work of that kind; but if he is absent while a joint is being filled, he can judge of the amount of mortar used by prodding the joint with a bar or trowel, and after removing it pouring water into the hole. The water will quickly disappear if the work is faulty.

Appearance of the Face of the Wall. The face of the wall should be kept clean; mortar not being allowed to run down the face of the completed portion. To keep the face clean, however, the mason who spreads the beds leave a 3-inch margin along the front so that when the stone settles into place the mortar will not flush out and run down the face. The mortar may not spread under the weight of the stone to cover the entire 3 inches, but the remainder can readily be filled when the pointing is done. This method of spreading a bed is advantageous in pointing a wall because it usually leaves about an inch of the joint unfilled and consequently the contractor will find the joints ready to be pointed save for sweeping and wetting. Further,

the railroad company is more likely to get a serviceable job of pointing because the joint is more likely to be clear of mortar farther back and thus leave more of the joint to be filled by the pointing mortar.

Pointing. If the joints are full of the mortar used in laying the stone, they should be cleaned out to the distance called for in the specifications; and then they should be swept and wetted before the pointing mortar is introduced. When a joint is found that is too tight to permit of its being readily filled with the pointing mortar, it should be cut large enough to admit of the work being well done.

The joint after being filled is finished in one of three ways, commonly known as bead, ribbon, and tuck pointing. The first method leaves a half round projection of mortar which looks well but is not durable. Ribbon pointing is done by smoothing over the mortar after the joint is full and then trimming the edges to a line with a trowel, which makes a serviceable pointing but takes longer and is consequently more expensive than

either of the other methods. Buck is the opposite of bead pointing, that is it leaves the mortar half round but concave instead of convex; and is both durable and inexpensive.

Materials and Accounts. An inspector is usually required to keep a daily record of the number of men employed by the contractor. If any of the work is done by "force account," the inspector is expected to keep a check on the foreman so that the bill against the railroad company will be only for the actual work performed. Under some engineers the inspector is required to measure each course as it is laid, - the measurements to be used in figuring quantities. If the company furnishes any of the material, the inspector should see that a supply is on hand when needed and he should also keep a record of where this material is used so that it can be charged to the proper account.

These minor duties differ under different engineers and the inspector will doubtless receive instructions from his superior regarding them.

3. Relations with Workmen and Contractor.

In his dealings with the men on the work the inspector should exercise judgment and tact. He should not act as though he expected dishonest work, or the attempt will surely be made to deceive him. On the other hand, he should be on the lookout for mistakes, but should watch for them in a straight forward gentlemanly way that will command respect.

Relations to Workmen. Considerable has been written concerning the grade of work to be expected of masons employed by contractors. Some engineers claim that after a mason has worked for a contractor for a time he loses the ability or the inclination to do good work. In this connection it is interesting to note that after a number of years during which a certain western railroad did all of its own masonry with men employed directly by itself, the company has dispensed with its mason crews and now lets all masonry to contractors. This company claims that a better grade of masonry is secured and for a less price per yard than if done with its

own men. Some of the work done by the company's masons has been torn down to make room for improvements; and some of these walls have been found to be very poor, large holes having been left without being filled with even dry stone.

Inspectors on railroad work usually have the power to discharge any of the contractor's men who persist in doing faulty work; and though this is a severe measure it may be necessary to employ it in order to have proper care used in the work. Liniemen should of course be shown to apprentices, but men who constantly disobey the inspectors' instructions should not be allowed on the walls.

Relations with Contractor. In his dealings with the contractor the inspector should be as accommodating and obliging as possible and at the same time secure the best results for his own employers. An inspector can often allow substitutions that will be a saving to the contractor and still be no detriment to the work, and by doing so he is in a position to ask and expect more from the contractor that will be of considerable benefit to the work.

It is possible for the inspector to insist upon the performance of the work to the exact letter of the specifications and still secure no stronger or better work than if the specifications were followed with judgment.

Occasionally an inspector by his narrowmindedness may cause a contractor serious financial loss and possibly ruin.

Inspectors, more especially young and inexperienced ones, often have the impression that the contractor's only desire is to slight the work as much as possible in order to make larger profits. This is no doubt true of some contractors, but they rarely get a chance to bid on railroad work. Almost all railroads award their work at private lettings, and the contractors doing work under these conditions are as anxious to preserve their reputations by doing the work well as the railroad company is to have the work well done.

An inspector of railroad masonry need not be a man of superior mental ability, but he must be observing and be able to make the proper deductions from his observations. He should be tactful, able to exercise good

judgment, and above all he must be
honest.





